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# **CRITERIA FOR A RECOMMENDED STANDARD**

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## **Occupational Exposure to Respirable Coal Mine Dust**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES**  
Public Health Service  
Centers for Disease Control and Prevention  
National Institute for Occupational Safety and Health  
Education and Information Division  
Cincinnati, Ohio

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## FOREWORD

In the Federal Mine Safety and Health Act of 1977 (Public Law 95-164) and the Occupational Safety and Health Act of 1970 (Public Law 91-596), Congress declared that its purpose was to assure, insofar as possible, safe and healthful working conditions for every working man and woman and to preserve our human resources. In these Acts, the National Institute for Occupational Safety and Health (NIOSH) is charged with recommending occupational safety and health standards and describing exposure levels that are safe for various periods of employment, including but not limited to the exposures at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience. By means of criteria documents, NIOSH communicates these recommended standards to regulatory agencies (including the Occupational Safety and Health Administration [OSHA] and the Mine Safety and Health Administration [MSHA]) and to others in the community of occupational safety and health.

Criteria documents provide the scientific basis for new occupational safety and health standards. These documents generally contain a critical review of the scientific and technical information available on the prevalence of hazards, the existence of safety and health risks, and the adequacy of control methods. In addition to transmitting these documents to the Department of Labor, NIOSH also distributes them to health professionals in academic institutions, industry, organized labor, public interest groups, and other government agencies.

This criteria document reviews available information about the adverse health effects associated with exposure to respirable coal mine dust. Epidemiological studies have clearly demonstrated that miners have an elevated risk of developing occupational respiratory diseases when they are exposed to respirable coal mine dust over a working lifetime at the current MSHA permissible exposure limit (PEL) of  $2 \text{ mg/m}^3$ . The exposure limit of  $1 \text{ mg/m}^3$  recommended in this document is based on an evaluation of health effects data, sampling and analytical feasibility, and technological feasibility. However, this recommended exposure limit (REL) does not ensure that miners exposed at this concentration over a working lifetime will have a zero risk of developing occupational respiratory diseases. Therefore, NIOSH recommends additional measures to protect miners' health: (1) keeping worker exposures as far below the REL as feasible through the use of engineering controls and work practices, (2) frequent monitoring of worker exposures, and (3) participation of miners in the recommended medical screening and surveillance program.

Future research may provide new and more effective methods for minimizing occupational health risks among coal miners, including new methods for controlling exposures to respirable coal mine dust, more accurate and reliable measures of worker exposures, improved methods for earlier detection of disease, and new medical interventions to halt or reverse disease progression.

If future developments permit a lower exposure limit that is both technologically feasible and prudent for the public health, NIOSH will revise its recommended standard. Until then, adherence to the REL of 1 mg/m<sup>3</sup> will minimize the risk of developing occupational respiratory diseases.

A handwritten signature in black ink, appearing to read "L. Rosenstock". The signature is fluid and cursive, with a large initial "L" and a long, sweeping underline.

Linda Rosenstock, M.D., M.P.H.  
Director, National Institute for  
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## ABSTRACT

This document examines the occupational health risks associated with exposures to respirable coal mine dust over a working lifetime. Such exposures are associated with the development of occupational respiratory diseases, including simple coal workers' pneumoconiosis (CWP), progressive massive fibrosis (PMF), and chronic obstructive pulmonary disease (COPD). Epidemiological studies have clearly demonstrated that miners have an elevated risk of developing simple CWP, PMF, or deficits in lung function when they are exposed to respirable coal mine dust over a working lifetime at the current Mine Safety and Health Administration (MSHA) permissible exposure limit (PEL) of  $2 \text{ mg/m}^3$ . Coal miners who are exposed to respirable crystalline silica are also at risk of developing silicosis or mixed-dust pneumoconiosis.

The National Institute for Occupational Safety and Health (NIOSH) recommends that exposures to respirable coal mine dust be limited to  $1 \text{ mg/m}^3$  as a time-weighted average (TWA) concentration for up to 10 hr/day during a 40-hr workweek, measured according to current MSHA methods. NIOSH recommends that sampling be conducted with a device that operates in accordance with the NIOSH accuracy criteria and the international definition of respirable dust. The  $1\text{-mg/m}^3$  REL is equivalent to  $0.9 \text{ mg/m}^3$  when measured according to these NIOSH recommended sampling criteria. The NIOSH REL represents the upper limit of exposure for each worker during each work shift and shall not be adjusted upward to account for measurement uncertainty. To minimize the risk of adverse health effects, exposures shall be kept as far below the REL as feasible using engineering controls and work practices.

Recommendations are made for minimizing the occupational health risks encountered by underground and surface coal miners. These recommendations pertain to respirable coal mine dust sampling to monitor worker exposures, use of personal protective equipment (including training and fit-testing for the use of respirators), and medical screening and surveillance examinations (including preplacement and periodic chest X-rays and spirometry).



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## ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AEC	U.S. Atomic Energy Commission
ANOVA	Analysis of variance
ATS	American Thoracic Society
BAL	Bronchoalveolar lavage
BMRC	British Medical Research Council
BOM	U.S. Bureau of Mines
Btu	British thermal unit
CEN	Comité Européen de Normalisation
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CI	Confidence interval
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
CPSU	Coal mine dust personal sampler unit
CWP	Coal workers' pneumoconiosis
DLCO	Diffusing capacity of the lung for carbon monoxide
Fed. Reg.	Federal Register
FEV <sub>1</sub>	Forced expiratory volume in 1 second
FVC	Forced vital capacity
gh	Gram hour(s)
gh/m <sup>3</sup>	Gram hour(s) per cubic meter
GSD	Geometric standard deviation
HHE	Health hazard evaluation
hr	Hour(s)
ILO	International Labour Office
ISO	International Standards Organization
L	Liter(s)
L/min	Liter(s) per minute
LLN	Lower limit of normal

LOD	Limit of detection
LOQ	Limit of quantitation
MAQ	Minimum accurately quantifiable concentration
MCE	Mixed cellulose ester
mg/m <sup>3</sup>	Milligram(s) per cubic meter
mg-yr/m <sup>3</sup>	Milligram year(s) per cubic meter
min	Minute(s)
ml	Milliliter(s)
MMD	Mass median diameter
MMU	Mechanized mining unit
MRE	Mining Research Establishment of the National Coal Board, London, England
MSHA	Mine Safety and Health Administration
MVV	Maximum voluntary ventilation
NIOSH	National Institute for Occupational Safety and Health
n	Nanoliter(s)
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
psi	Pounds per square inch
PMF	Progressive massive fibrosis
PMNs	Polymorphonuclear leukocytes
PVC	Polyvinyl chloride
REL	Recommended exposure limit
RV	Residual volume
SAR	Supplied-air respirator
SCBA	Self-contained breathing apparatus
SCSR	Self-contained self rescuer
SD	Arithmetic standard deviation
SIP	Spot inspection program
SMR	Standardized mortality ratio
TLC	Total lung capacity
TLV	Threshold limit value
TNF	Tumor necrosis factor
TWA	Time-weighted average
UCL	Upper confidence limit
UK	United Kingdom
USC	United States Code
VC	Vital capacity

## GLOSSARY

**Active workings:** Any place in a coal mine where miners are normally required to work or travel [30 CFR 70.2].

**Aerodynamic diameter:** The diameter of a sphere with a density  $1 \text{ g/cm}^3$  and with the same stopping time as the particle. Particles of a given aerodynamic diameter move within the air spaces of the respiratory system identically, regardless of density or shape.

**Black lung:** A common term used to refer to occupational respiratory disease in miners [Weeks and Wagner 1986].

**Chronic obstructive pulmonary disease (COPD):** Includes chronic bronchitis, impaired lung function, and emphysema. COPD is characterized by the irreversible (although sometimes variable) obstruction of lung airways.

**Clearance:** The translocation, transformation, and removal of deposited particles from the respiratory tract [Lioy et al. 1984].

**Coal face:** The exposed area of a coalbed from which coal is extracted [EIA 1989].

**Coal fines:** Coal with a maximum particle size that is usually less than one-sixteenth of an inch and rarely above one-eighth of an inch [EIA 1989].

**Coal rank:** A classification of coal based on the fixed carbon, volatile matter, and heating value of the coal. Coal rank indicates the progressive geological alteration (coalification) from lignite to anthracite [EIA 1989].

**Coal type:** A classification of coal based on physical characteristics or microscopic constituents [EIA 1989].

**Coal workers' pneumoconiosis (CWP):** A chronic dust disease of the lung arising from employment in an underground coal mine [30 USC 902]. In workers who are or have been exposed to coal mine dust, diagnosis is based on the radiographic classification of the size, shape, profusion, and extent of opacities in the lungs.

**Coefficient of variation (CV):** The CV is a measure of relative dispersion; it is also known as relative standard deviation and defined as the standard deviation/mean [Leidel et al. 1977].

**Concentration:** The amount of a substance contained per unit volume of air [30 CFR 70.2].

**Confidence interval (CI), confidence limits (CLs):** A range of values (determined by the degree of presumed random variability in the data) within which a parameter (e.g., a mean) is believed to lie with the specified level of confidence. The boundaries of a CI are the CLs [Last 1983]. These include the lower confidence limit (LCL) and the upper confidence limit (UCL).

**Continuous mining:** A mining method used in room-and-pillar mining in which the coal is removed from the coal face in one operation using a continuous mining machine.

**Conventional mining:** A mining method used in room-and-pillar mining in which the coal face is cut so that it breaks easily when blasted (with either explosives or high-pressure air). The broken coal is then loaded onto conveyors or into shuttle carts for removal to the surface.

**Crystalline silica (or free silica):** Silicon dioxide (SiO<sub>2</sub>). "Crystalline" refers to the orientation of SiO<sub>2</sub> molecules in a fixed pattern as opposed to a nonperiodic, random molecular arrangement defined as amorphous. The three most common crystalline forms of free silica encountered in general industry are quartz, tridymite, and cristobalite [NIOSH 1974]. In coal mines, the predominant form is quartz.

**Culm:** Fine anthracite.

**Culm bank:** The hillside where waste from anthracite mines is dumped.

**Deposition:** The collection of inhaled airborne particles by the respiratory tract and the initial regional patterns of these deposited particles [Lioy et al. 1984].

**District manager:** The manager of the Coal Mine Safety and Health District in which the mine is located [30 CFR 70.2].

**Geometric mean (GM):** The GM is a measure of central tendency for a log-normal distribution [Leidel et al. 1977].

**Geometric standard deviation (GSD):** The GSD is a measure of relative dispersion (variability) of a lognormal distribution.

**Gob area:** The area of subsidence that occurs when roof supports are removed during longwall mining and the area caves in. The gob area then supports the overlying strata.

**Engineering controls:** Hazard controls designed into equipment and workplaces.

**Highwall:** The unexcavated face of exposed overburden or coal in a strip pit.

**Inby:** Toward the workings of a mine.

**Incidence:** The frequency of occurrence of new cases of a disease for a given period.

**Incidence rate:** The rate at which new events occur in a population. The number of new events (e.g., new cases of a disease diagnosed or reported during a defined period) is divided by the number of persons in the population in which the cases occurred [Last 1983].

**Inhalable dust:** The particulate mass fraction of dust in the mine environment that is hazardous when deposited anywhere in the respiratory tract [ACGIH 1994].

**Longwall mining:** A system of mining in which long sections of coal (also called panels) up to 1,000 ft are removed by a cutting machine without leaving pillars of coal for support. A movable, powered roof support system is used to support the roof in the working area; when these supports are moved, the area (gob area) caves in and supports the overlying strata.

**Mechanized mining unit (MMU):** A unit of mining equipment (including hand-loading equipment) used for the production of material [30 CFR 70.2].

**MRE instrument:** The gravimetric dust sampler with a four-channel horizontal elutriator developed by the Mining Research Establishment of the National Coal Board, London, England [30 CFR 70.2].

**Normal production shift:** A production shift during which the amount of material produced in an MMU is at least 50% of the average production reported for the last set of five valid samples; or, the amount of material produced by a new MMU before five valid samples are taken [30 CFR 70.2].

**Outby:** Toward the shaft or entry of a mine.

**Overburden:** Any material, consolidated or unconsolidated, that overlies a coal deposit. Overburden ratio refers to the amount of overburden that must be removed to excavate a given quantity of coal [EIA 1989].

**Prevalence:** The frequency of all current cases of a disease (old and new) occurring within specific populations at a particular time.

**Prevalence rate (ratio):** The total number of all individuals who have an attribute or disease at a given time or during a given period divided by the population at risk of having the attribute or disease at this point in time or midway through the period [Last 1983].

**Progressive massive fibrosis (PMF):** Coal workers' complicated pneumoconiosis. Diagnosis is based on radiographic determination of the presence of large opacities of 1 cm or larger.

**Quartz:** Crystalline silicon dioxide (SiO<sub>2</sub>) not chemically combined with other substances and having a distinctive physical structure [30 CFR 70.2].

**Regression analysis:** Given data on a dependent variable *Y* and an independent variable *X*, regression analysis involves finding the best mathematical model (within some restricted form) to describe *Y* as a function of *X* or to predict *Y* from *X*. Most commonly, the model is linear. The

logistic model is also common in epidemiology. Multiple regression analysis considers  $Y$  as a function of more than one independent variable [Last 1983].

**Respirable coal mine dust:** That portion of airborne dust in coal mines that is capable of entering the gas-exchange regions of the lungs if inhaled; by convention, a particle-size-selective fraction of the total airborne dust; includes particles with aerodynamic diameters less than approximately 10  $\mu\text{m}$ .

**Respirable convention ( $E_R$ ):** The target sampling curve for instruments approximating the respirable fraction.  $E_R$  is defined at aerodynamic diameter  $D$  by ISO [1993], CEN [1993], and ACGIH [1994] in terms of the cumulative normal function  $\Phi$  as:

$$E_R = E_I \bullet \Phi[\ln[D_R/D]/\sigma_R]$$

where the indicated constants are  $D_R = 4.25 \mu\text{m}$  and  $\sigma_R = \ln[1.5]$ , and the *inhalable* convention  $E_I$  is defined by

$$E_I = 0.50 (1 + \exp[-0.06 D]), D < 100 \mu\text{m}$$

**Retention:** The temporal distribution of uncleared particles in the respiratory tract [Liroy et al. 1984].

**Room-and-pillar mining:** A system of mining in which the mine roof is supported primarily by coal pillars that are left at regular intervals [EIA 1989].

**Spoil:** Overburden removed in gaining access to the coal during surface coal mining.

**Thoracic dust:** The particulate mass fraction of dust in the mine environment that is hazardous when deposited anywhere within the lung airways and the gas-exchange region [ACGIH 1994].

**Time-weighted average (TWA):** Exposure of a worker over an 8-hr work shift as defined in 29 CFR 1910.1000(d)(1).

**Work practices:** Procedures followed by employers and workers to control hazards.

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